EUV Multilayer Fabrication

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ABSTRACT: In this poster, we review our use of tools & methods such as deposition flux simulation & ray-trace illumination modeling as applied to an extended history of EUVL coating projects. These methods offer insights into the successful fabrication of multilayers for all purposes, including analysis, specification determination, coating calibration and performance assessment. In our case, they have played a role our history of EUVL coatings:

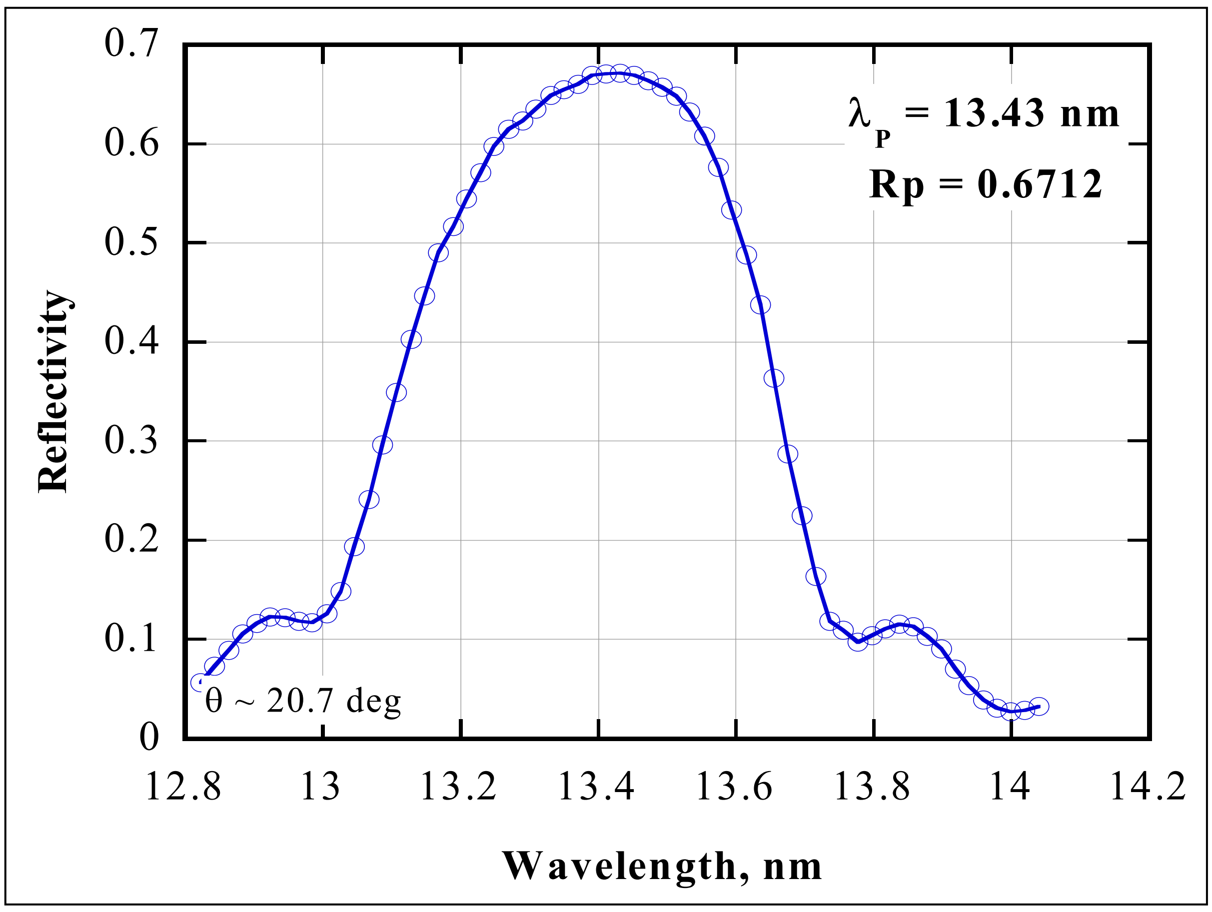
- 2-Optic imaging system (1999)
- >1000 Mask blanks (1999-2000)
- 360mm Condensor (2002)
- 2-Optic imaging system (2003)
- 2-Optic toroidal imaging system (2004)
- 6-Optic condensor/imaging system (2005)
- Wideband & High-Selective EUV multilayers

Facility & Metrology

- 6 Carousel Magnetron & 1 Ion-beam
- 5-Target Inline Magnetron
  - Loadlock, Linear Ion source, 4 process gas
  - 500x1500mm carrier /w velocity profiling
  - Dual-substrate spinning:
    (450mm dia x100mm & 175mm dia x 35mm)

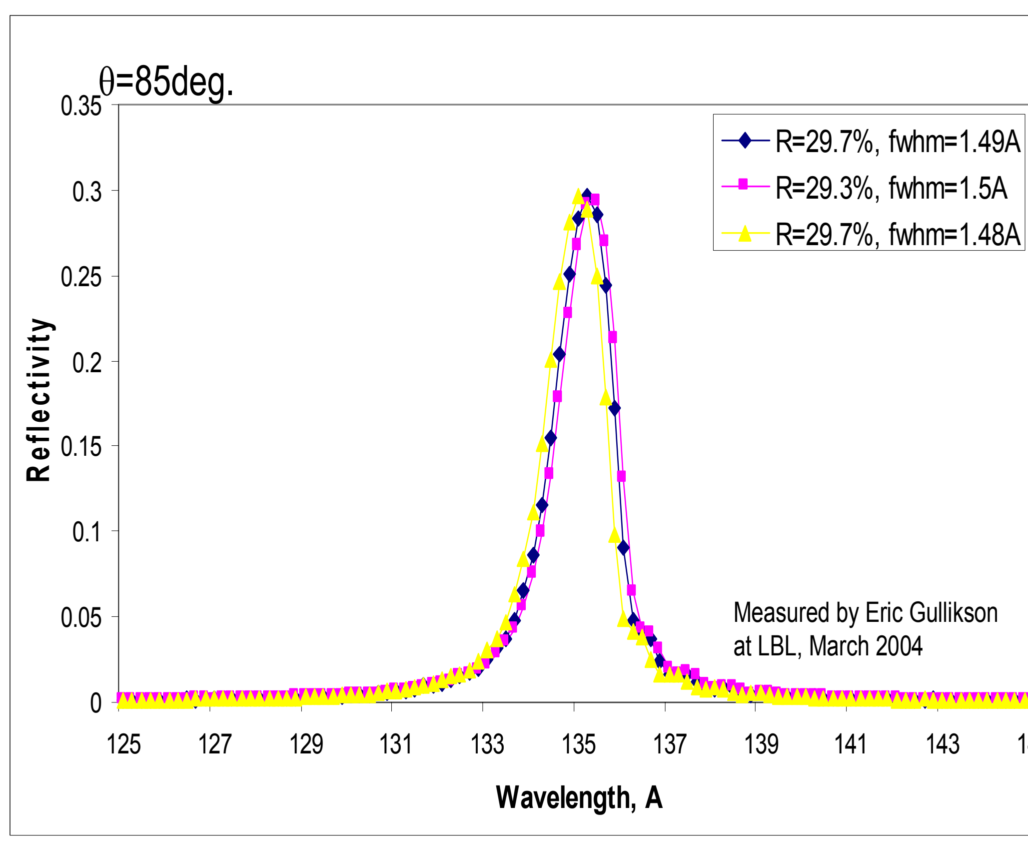
- Metrology:
  - Grazing-incidence x-ray reflectometry
    (Cu Kα, 3 instruments)
  - UV Spectrophotometer: 110-550 nm
    (refl & trans up to 200mm dia x 50mm thick)
  - Profilometer – Curvature
    (0.5 arc-sec precision)
  - AFM

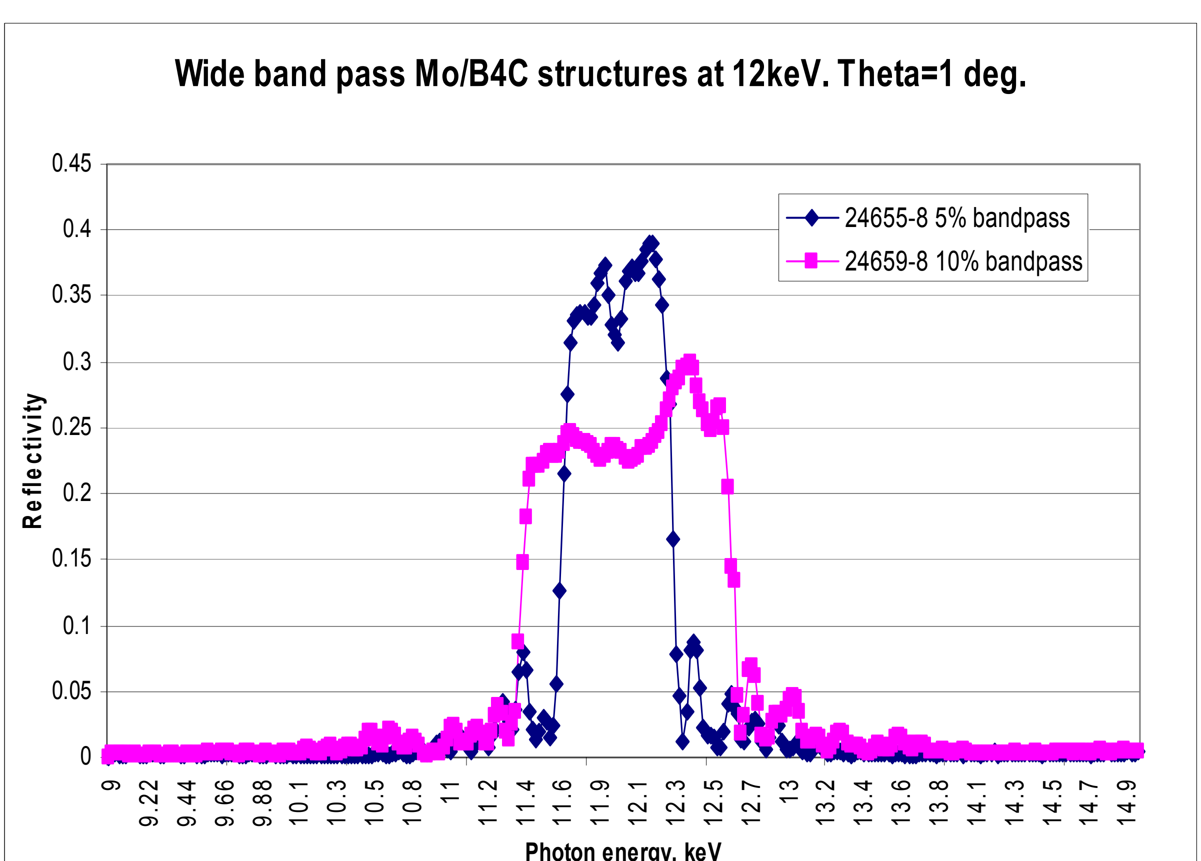
Reflectivity



Mo/Si ML
Ru/B4C Cap
200mm optic
Inline

SiC/Si ML
High-Selective
13.5nm



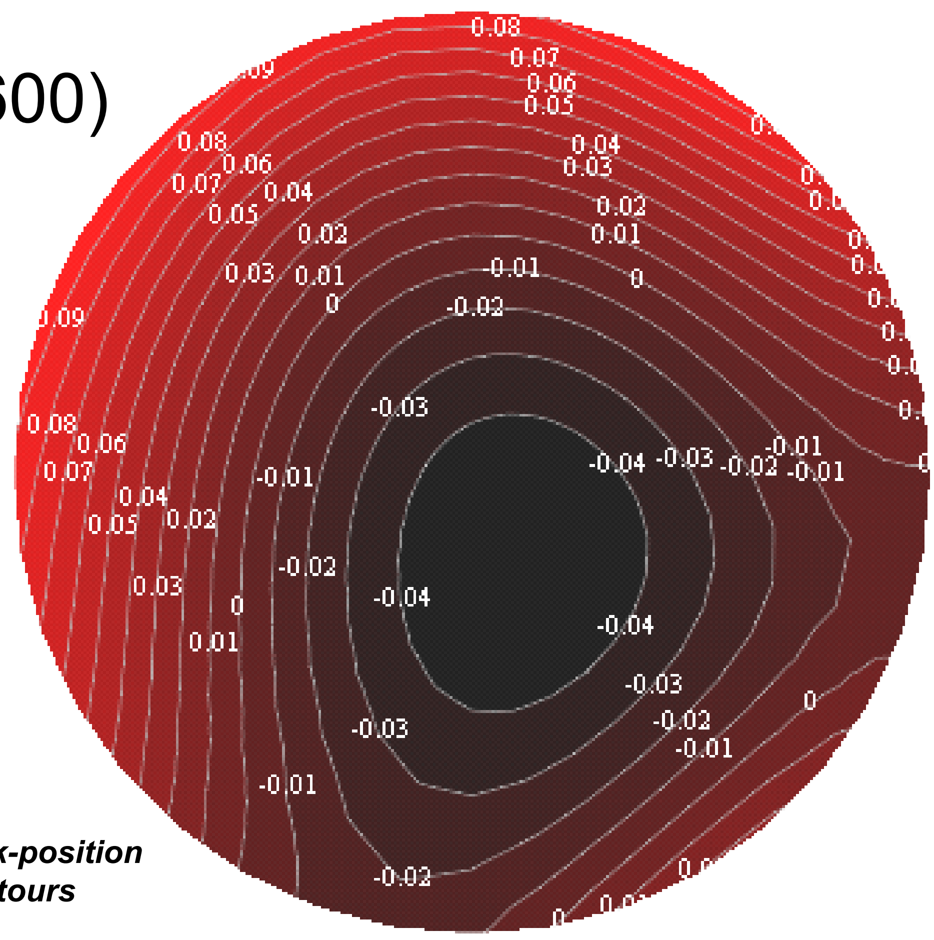


Mo/B4C ML
Wide-Band
12keV, 1deg

Imaging Systems

2-Optic Imaging System (2004)

- 200mm toroidal (R~350-600)
- 2D non-radial gradient
- Ru/B_4C topcoat
  (best R_p 67.1%)
- Achieve < ±1% wavelength on all four optics
  (2 sets of 2)

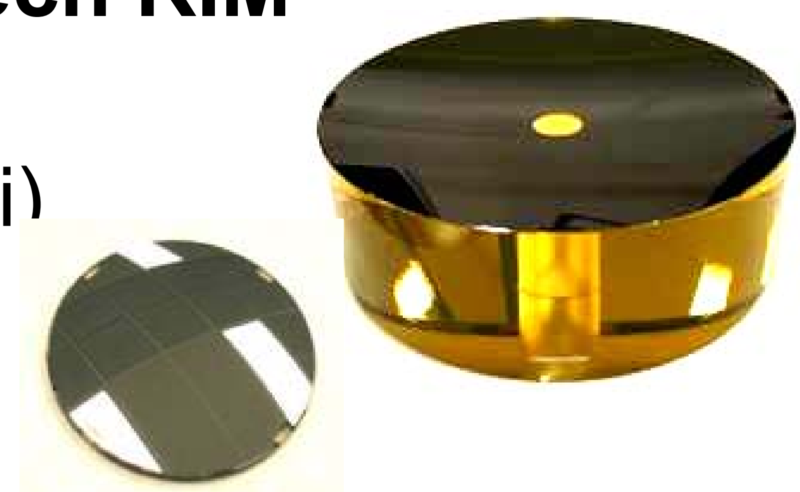


variation of peak-position
0.01nm contours

6-Optic Condensor/Imaging (2005)

Tinsley/Exitech RIM

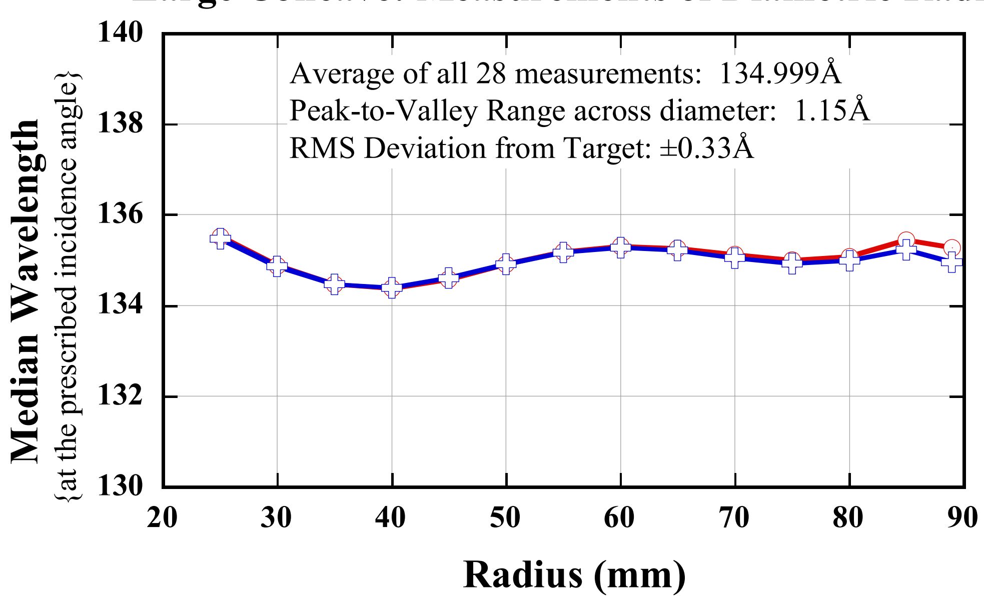
- 4 condensor (1 Ru, 3MoSi)
- 2 imaging (MoSi)

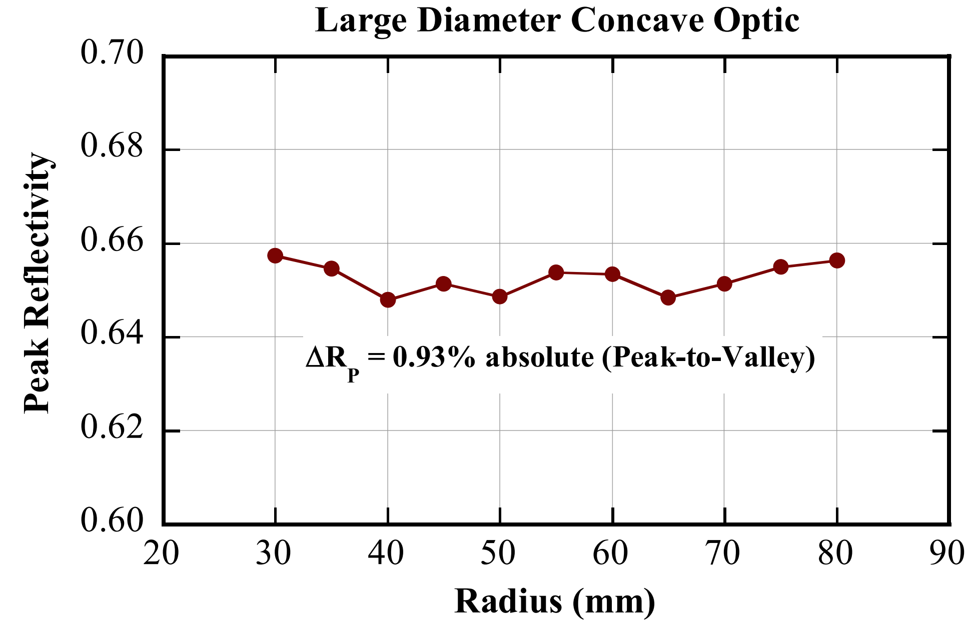


- Added Figure Error in imaging optics:
  – M1: 0.015nm (± 0.018nm λ in CA)
  – M2: <0.010nm (± 0.005nm λ in CA)

Imaging Systems

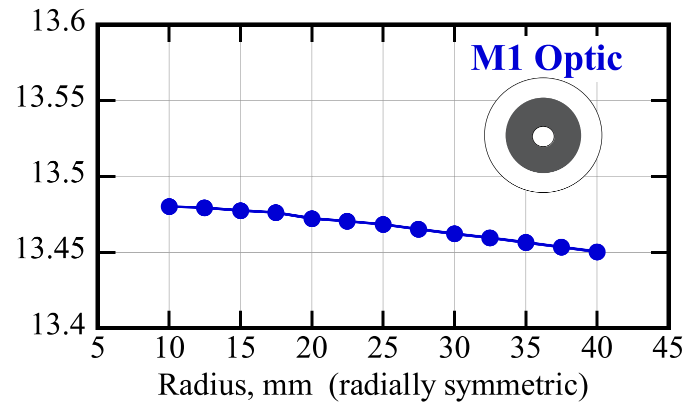
Schwarzschild Imaging (2003)

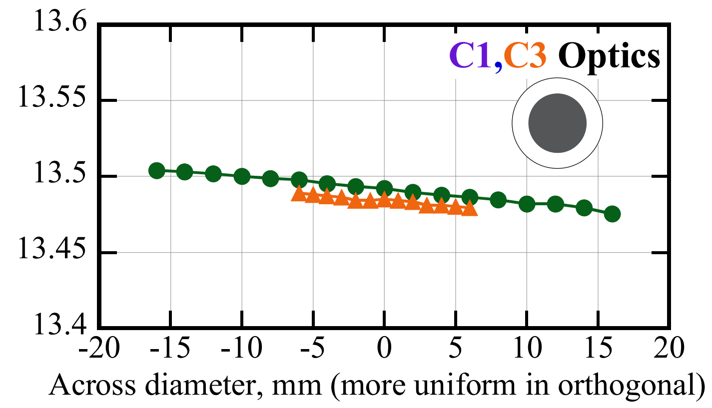


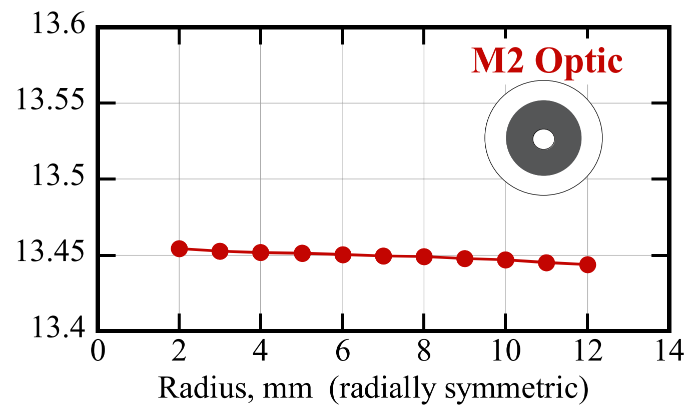


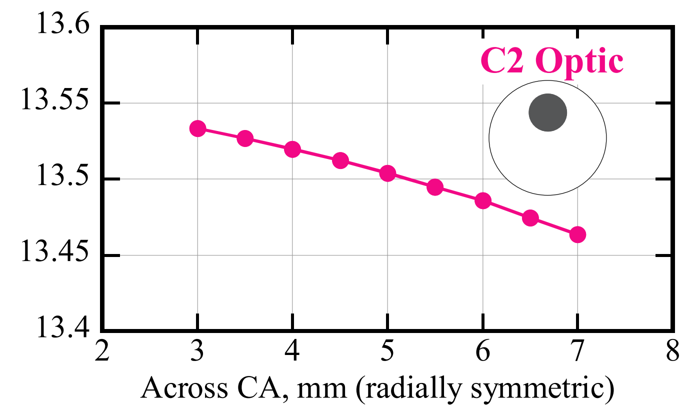
6-Optic Condensor/Imaging (2005)

Tinsley/Exitech RIM





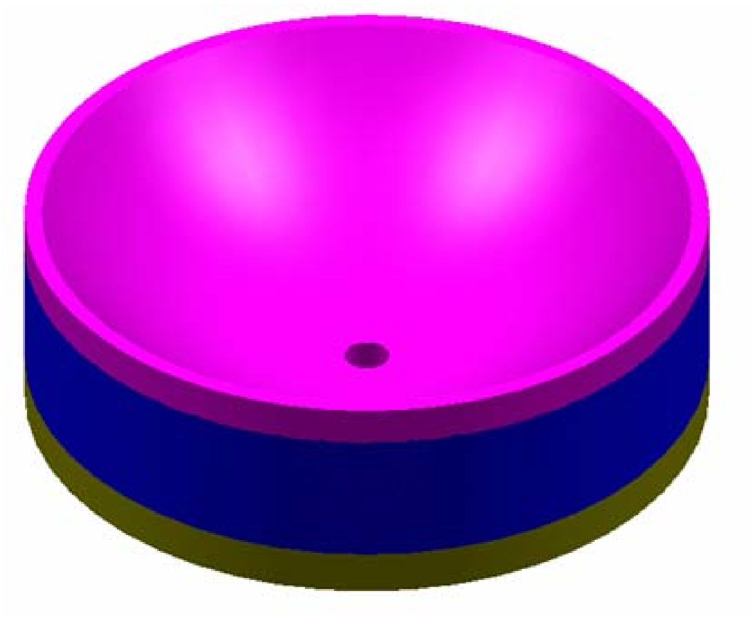


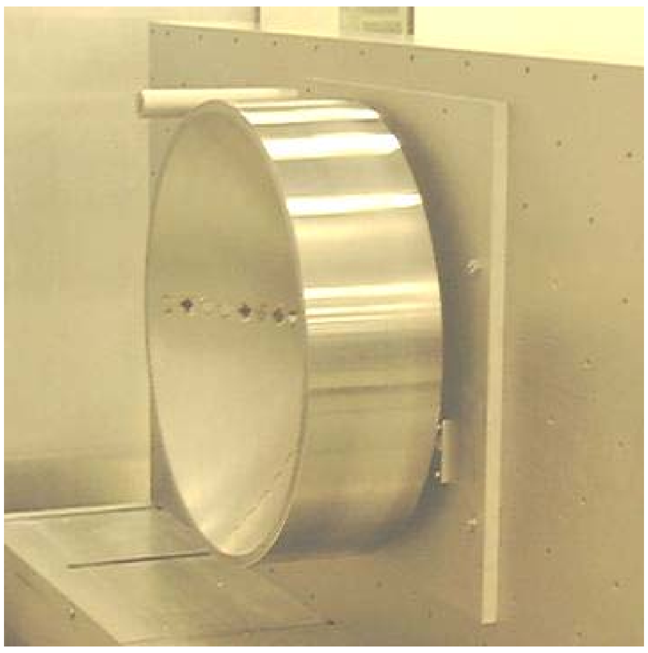


	Shape	Curvature	Diameter	CA Radii	$\Delta\lambda_C$ (PV)	Δthick (PV)	Δthick (rms)
M1	Concave	moderate	155mm	10-45mm	±0.018nm	±0.38nm	0.23nm
M2	Convex	moderate	78mm	3-12mm	±0.005nm	±0.10nm	0.04nm
C1	Concave	moderate	42mm	0-16mm	±0.013nm	±0.26nm	0.20nm
C2	Convex	very curved	18mm	3-7mm	±0.022nm	±0.45nm	0.37nm
C3	Concave	flat	25mm	0-6mm	±0.004nm	±0.10nm	0.08nm
C4	Flat	-n/a-	40mm	0-18mm	-n/a-	±0.30nm	-n/a-

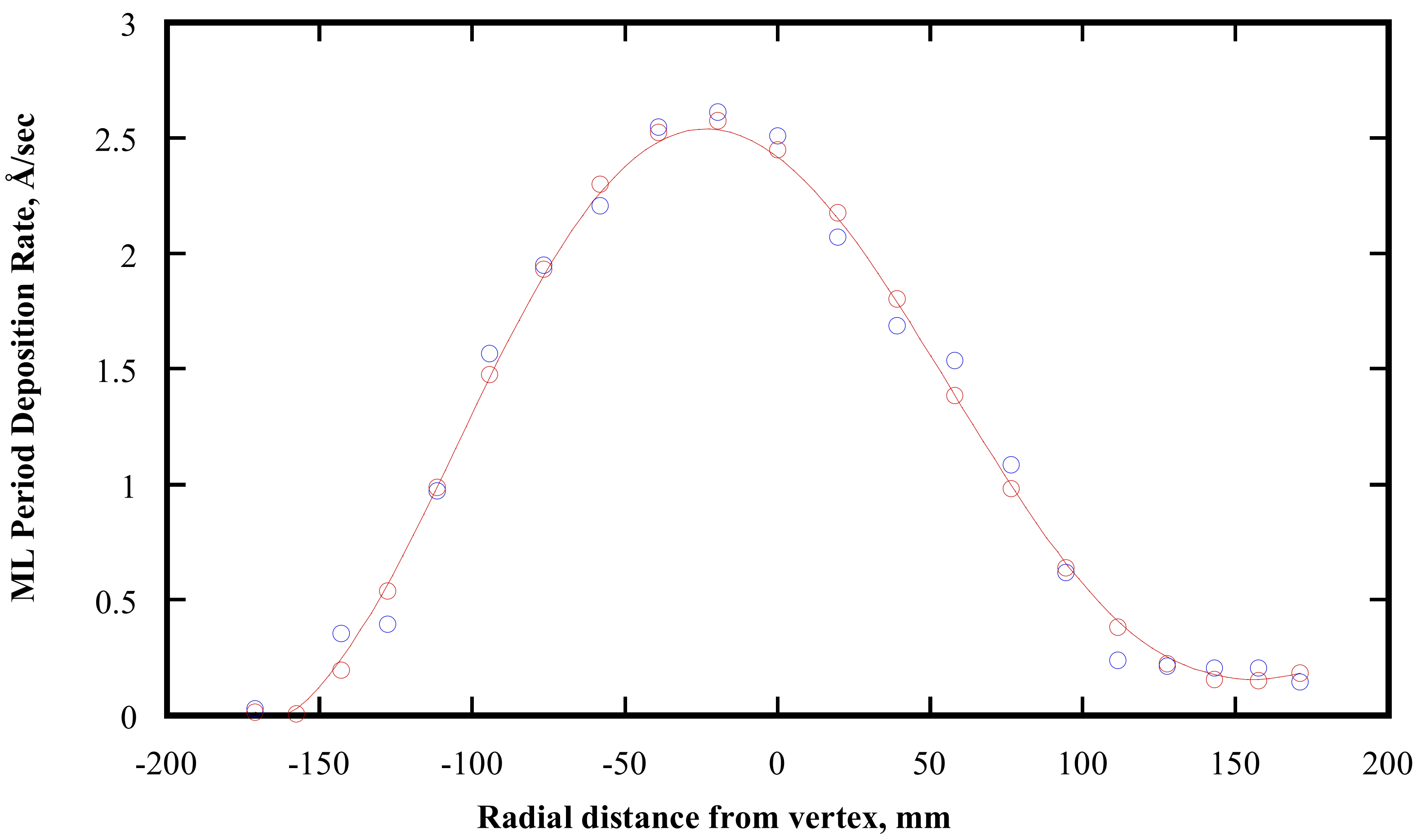
Deposition Simulation

360mm Condensor: 2D Graded Ellipse

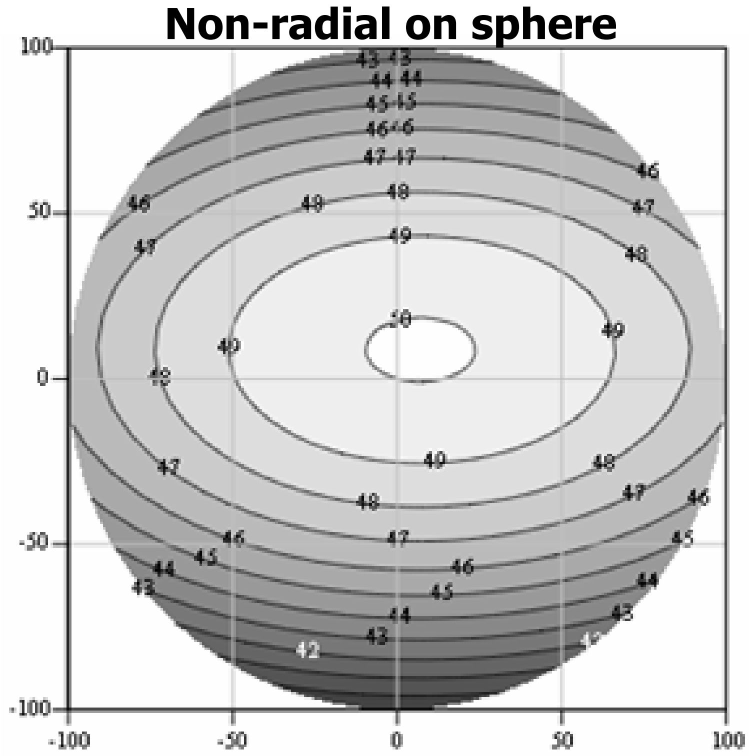




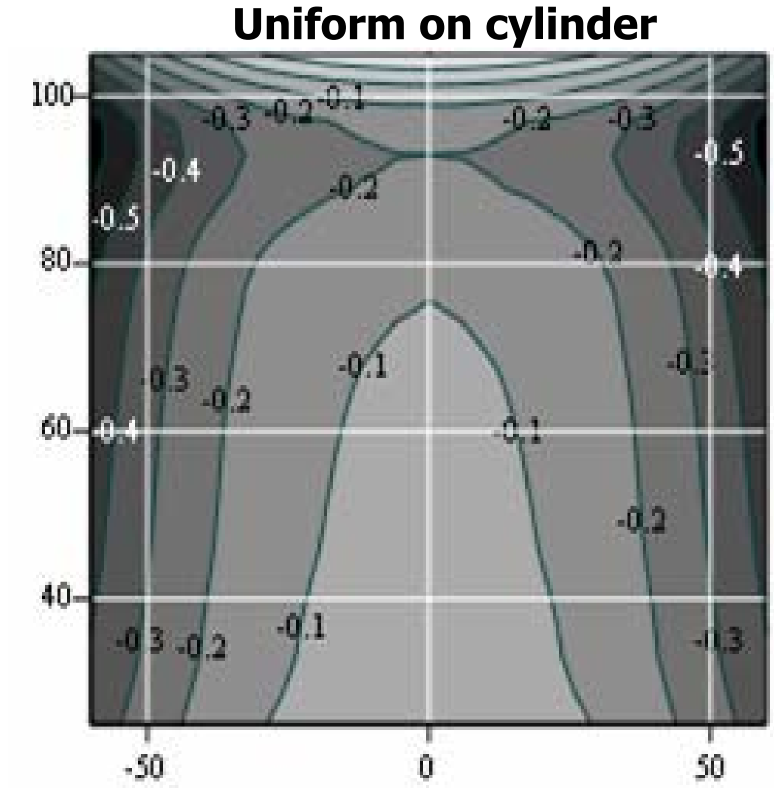
Deposition across the optic from a specific range of travel within the chamber



Non-radial on sphere



Uniform on cylinder



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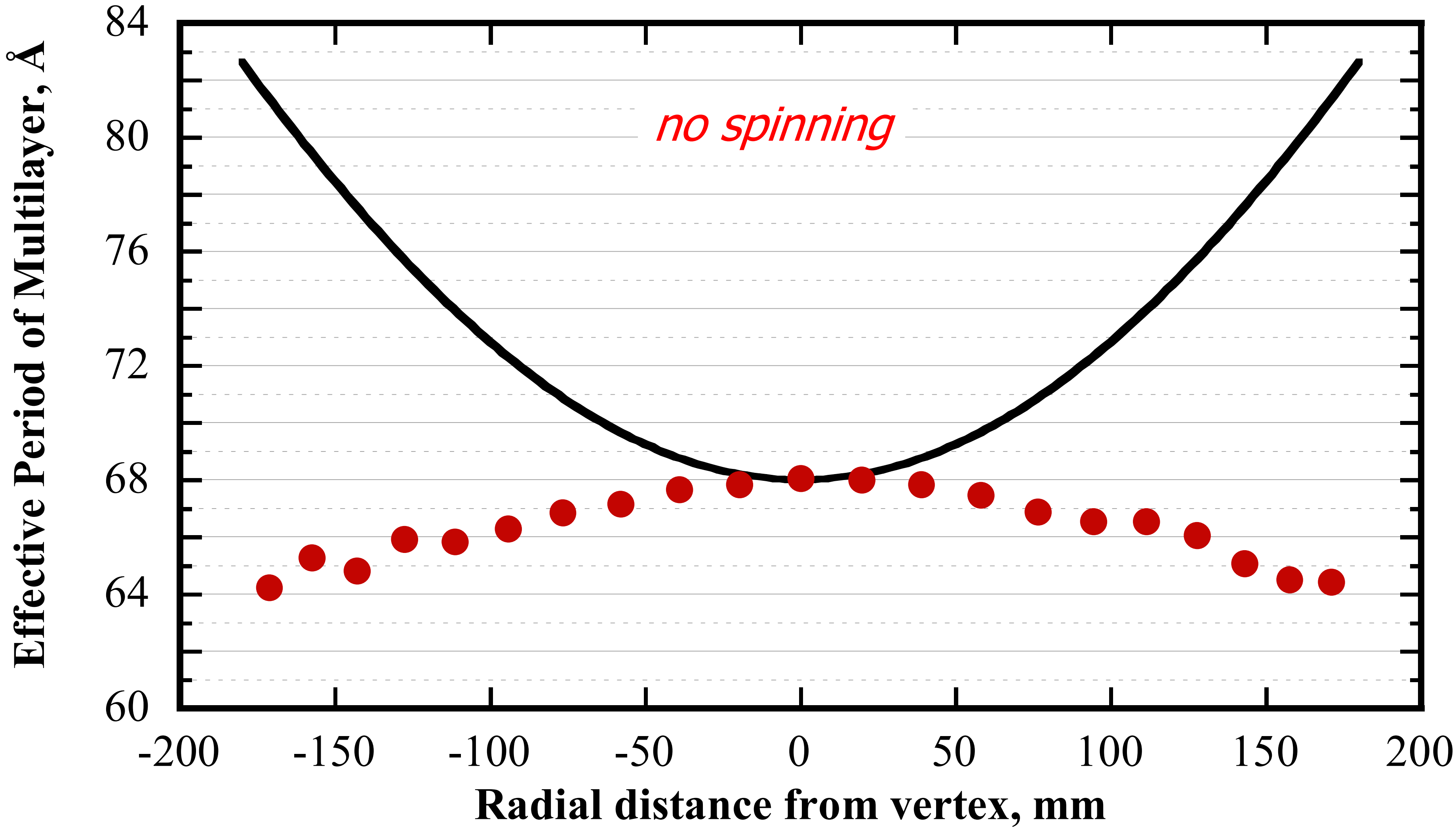
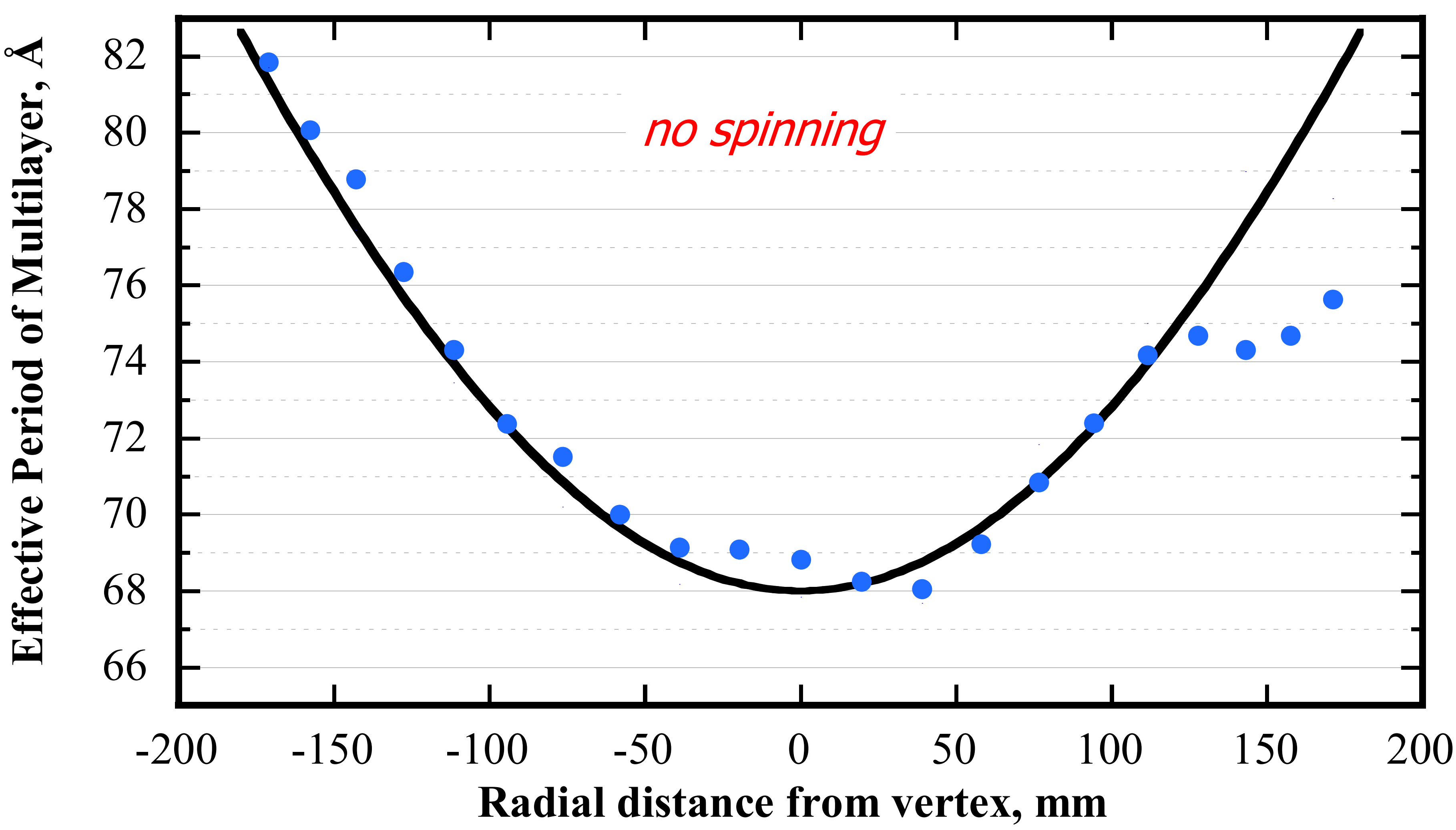
Deposition Simulation

360mm condensor: before utilizing velocity control



360mm condensor: after utilizing simulation-based solution for velocity profile

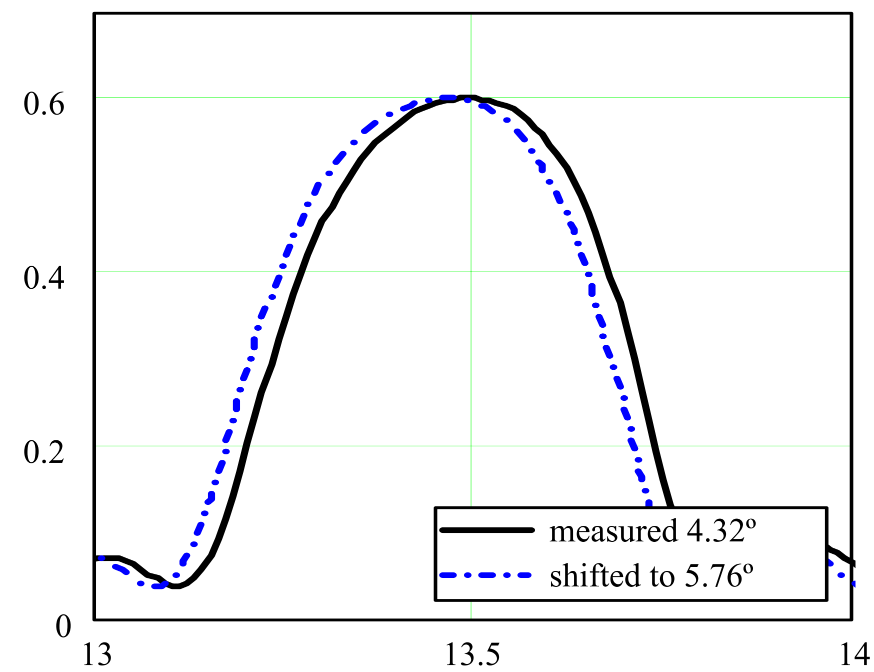


Ray-Tracing

ML impact to system illumination

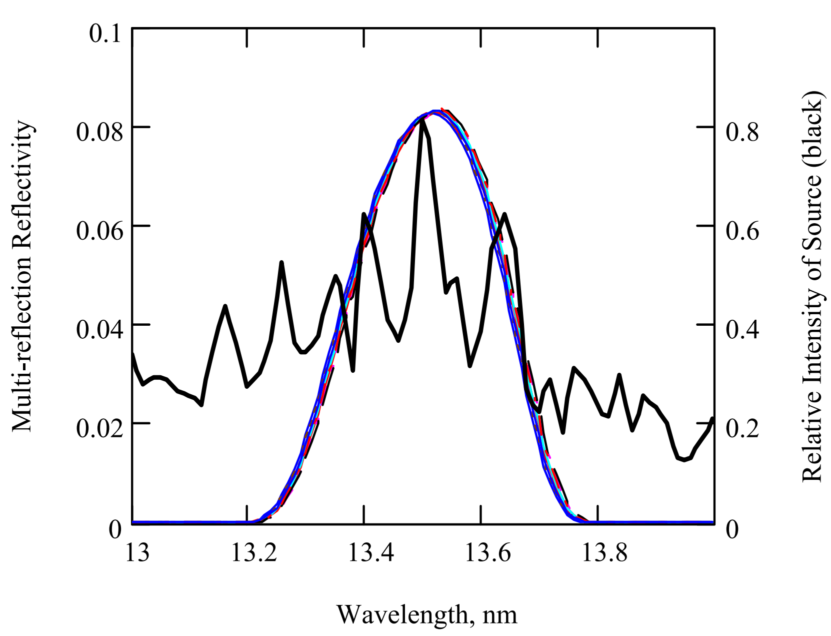
- Source has spectrum $I_O(\lambda)$
- Multiple beams (N) exit from each position, x_S, on the source
- Each position of the source illuminates the entire width of the reticle/detector image; it images a subset of positions, x_M, across the clear-aperture on each optic (M optics).
- The variation of the reflectivity spectra, $R(\lambda)$, on each optic is known. Functionalize the variation in peak wavelength with position ($\Delta\lambda_P$ vs x)
- Each ray has a different angle-of-incidence, g, on each optic. This value is different from the measurement angle, g_m, of the multilayer. The peak is shifted $\Delta\lambda_g$ from the g_m to g.

$$\Delta\lambda_\gamma = f\left(\cos(\gamma) / \cos(\gamma_m)\right)$$



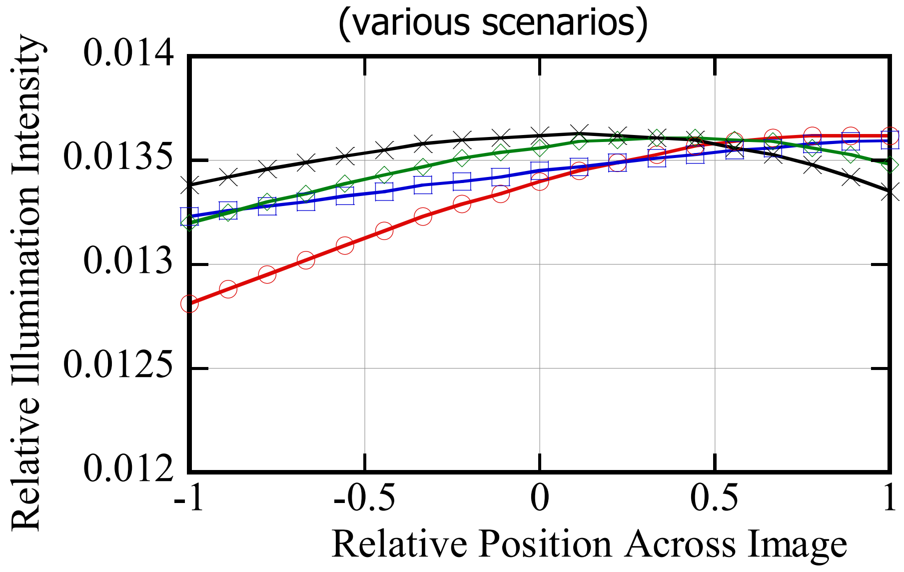
$$I(x) = \sum_N \left[\int_{\lambda_1}^{\lambda_2} I_o(\lambda) \cdot R_M(x_M, \lambda[\Delta\lambda_{mfg}, \Delta\lambda_{\gamma\ vs\ \gamma_m}]) \right]$$

- The source spectrum and the optic reflectivity spectra are multiplied and integrated in the bandwidth for each beam. The multiple N beams arriving at each reticle/detector position are then summed.



- How does illumination vary across reticle/detector?
- How does I(x) change from assumption of perfect coatings (identical & perfect uniform $R(\lambda)$) with actual measured spectra?
- Is there an effect of the actual source spectrum $I_o(\lambda)$ from some idealized constant value?
- What are individual effects of $\Delta\lambda$ & ΔRp variations in the ML coatings?
- What are the relative contributions to I(x) of each optic?
- With known expectations or prior results of coatings, can you make tradeoffs in total illumination (I_{avg}) vs illumination variation (ΔI) by changing the targeted specifications of individual optic-coatings?

Illumination Variation to the Detector
(various scenarios)



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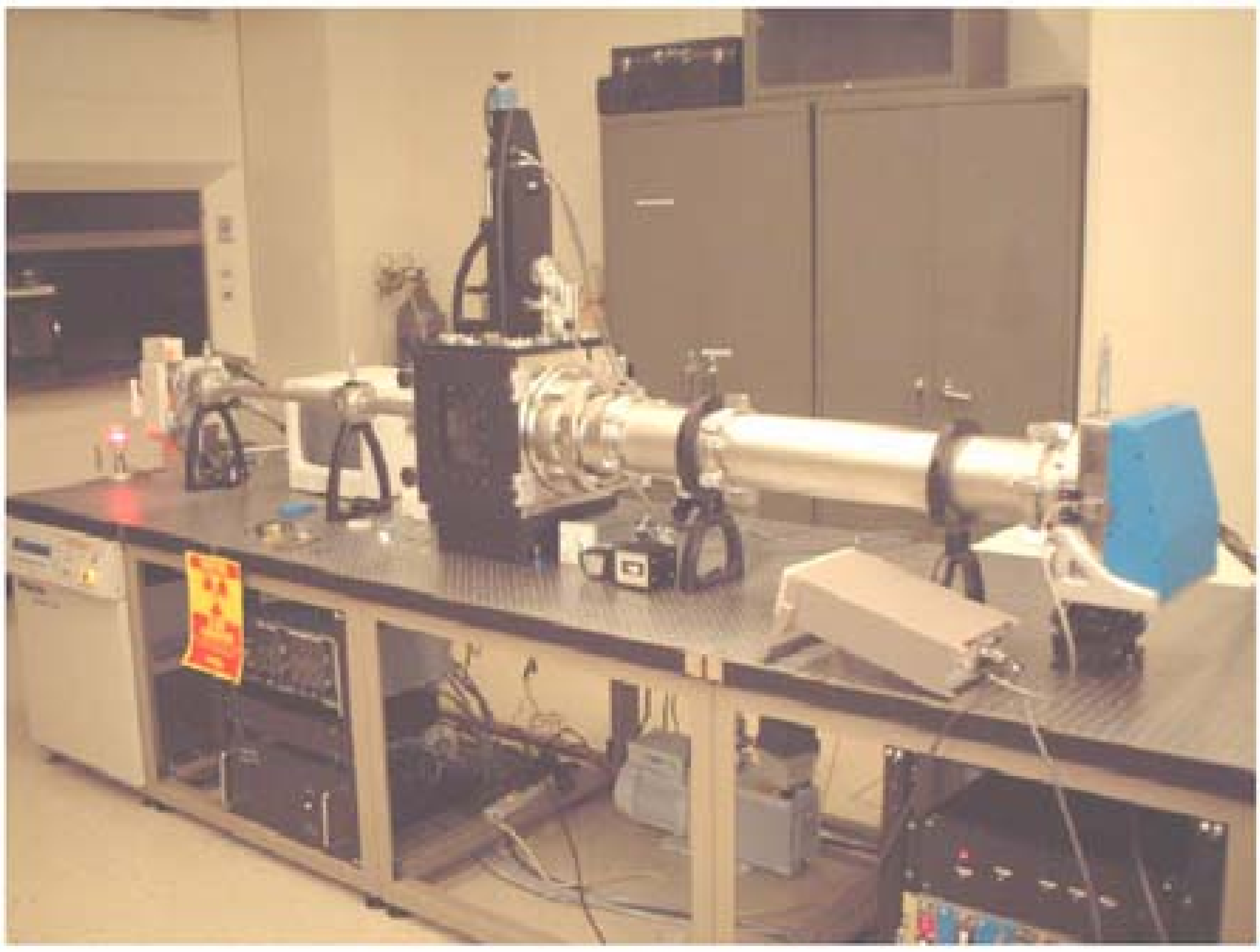
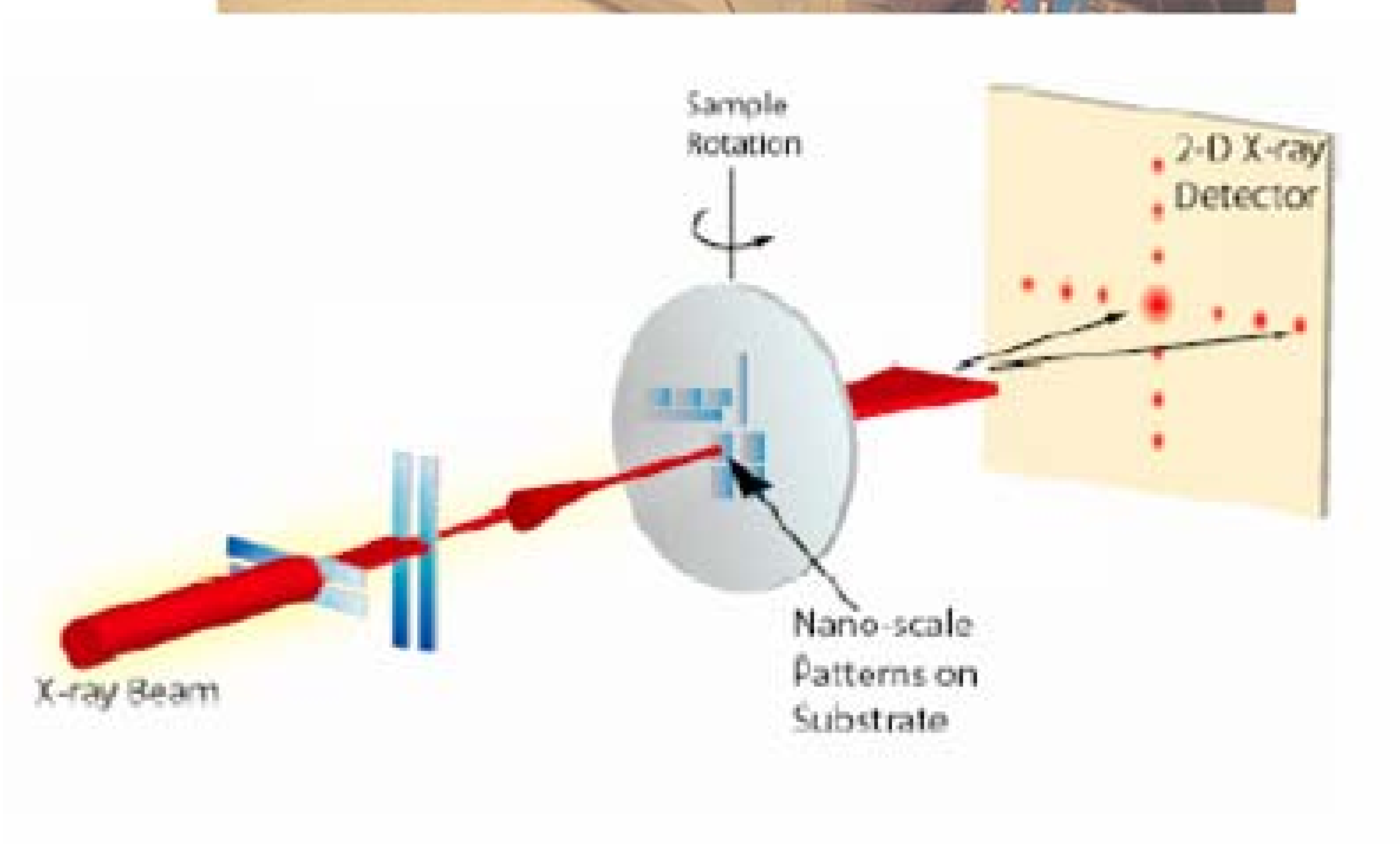
CD-SAXs Camera line-edge roughness





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